(12) UK Patent Application (19) GB (11) 2 177 625 A

(43) Application published 28 Jan 1987

(21) Application No 8614490

(22) Date of filing 13 Jun 1986

(30) Priority data

(31) 60/131329 (32) 17 Jun 1985 (33) JP

(71) Applicants
Noboru Inoue,
2-14-24 Asahicho, Takasagocho, Takasago-shi, Hyogo-ken, Japan
Fujimasa Industrial Co, Ltd,

(Incorporated in Japan),

956 Yoneda, Yonedacho, Takasago-shi, Hyogo-ken, Japan

(72) Inventor
Noboru Inoue

(74) Agent and/or Address for Service
F. J. Cleveland & Company, 40-43 Chancery Lane, London WC2A 1JQ

(51) INT CL^4
B03C 3/34

(52) Domestic classification (Edition I):
B2J 101 103 203 207 208 211 D1
B1D NAD PPC
B1T NAD
U1S 1270 1272 1364 1434 1485 1515 2405 B1D B1T B2J

(56) Documents cited

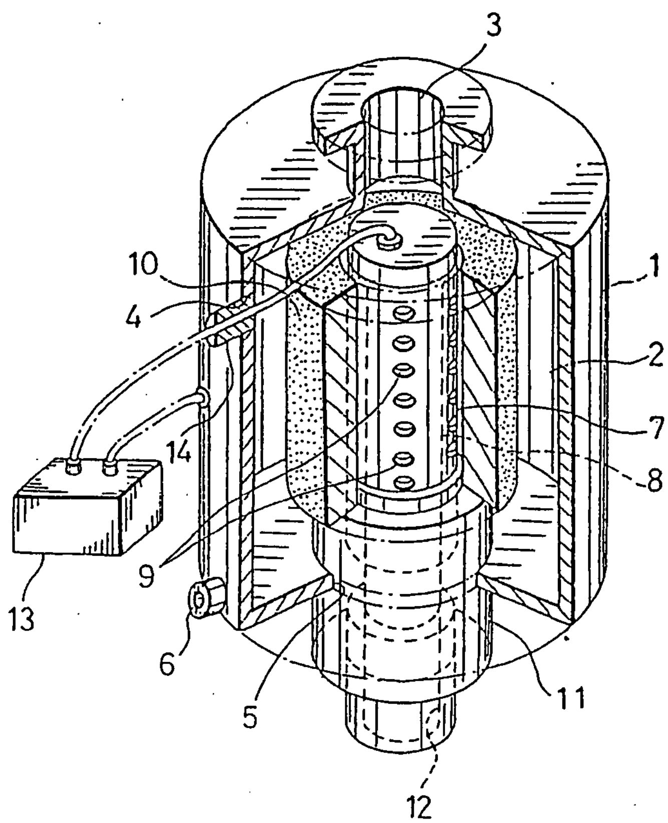
GB 1604670	EP A 0049454
GB 1491545	EP A 0035973
GB 1408040	US 4205969
GB 1102530	US 3999964

(58) Field of search
B2J
Selected US specifications from IPC sub-class B03C

(54) **Fluid filtering apparatus**

(57) A fluid filtering apparatus wherein the surface of one of opposing electrodes 1, 7 is covered with a filter 10 made of dielectric substance. A voltage is impressed across said electrodes 1, 7 to polarize the filter 10 and thereby to generate a zeta potential on the surface thereof so that impurities such as colloid particles contained in fluid to be treated and introduced into a region between said electrodes 1, 7 are attracted by a Coulomb's force onto the filter surface. The colloid particles having lost the zeta potential at the filter surface cohere together to form a cake layer on the filter surface so that the cake layer thus formed on the filter surface provides for filteration with a precision higher than achieved by the filter itself. In other embodiments, an outer electrode (15, Figures 4 to 6) surrounds the charging electrode (1), the feed is introduced tangentially (Figures 7 and 8) or a plurality of inner electrodes is used (Figures 9 and 10).

FIG. 1



GB 2 177 625 A

FIG. 1

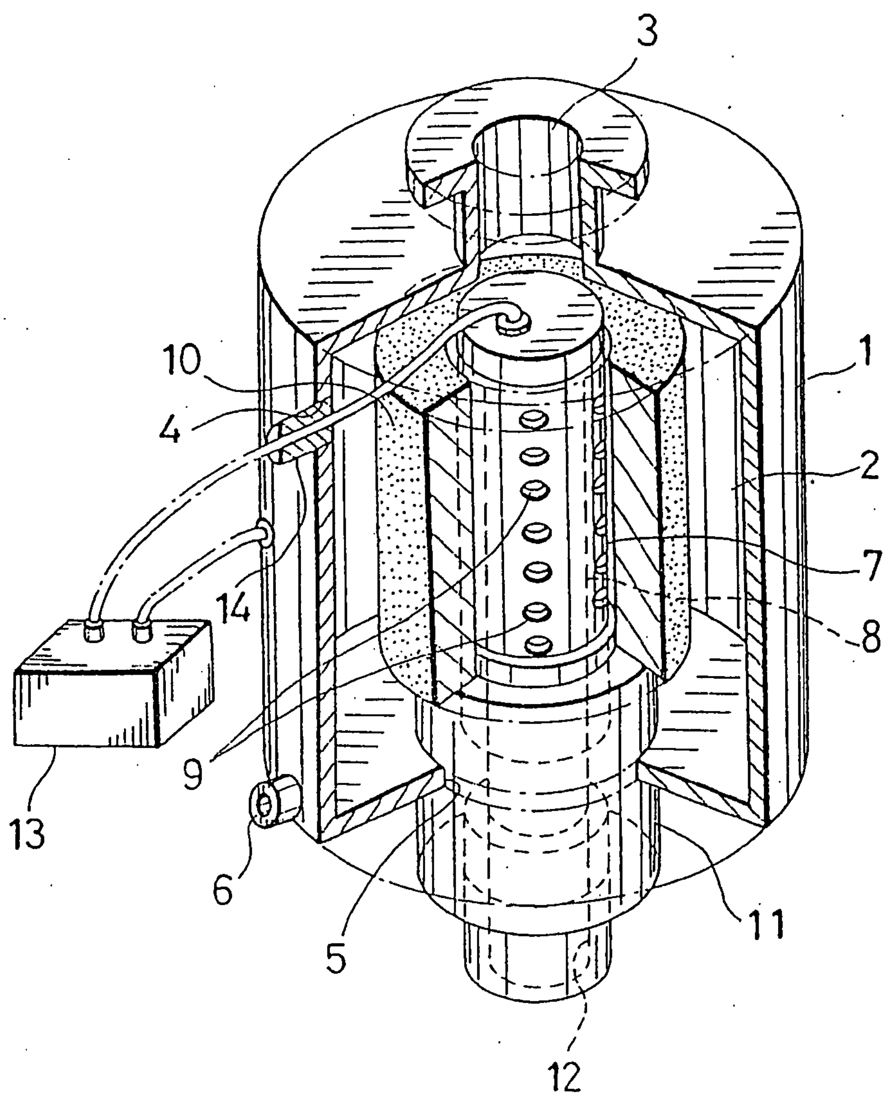


FIG. 2

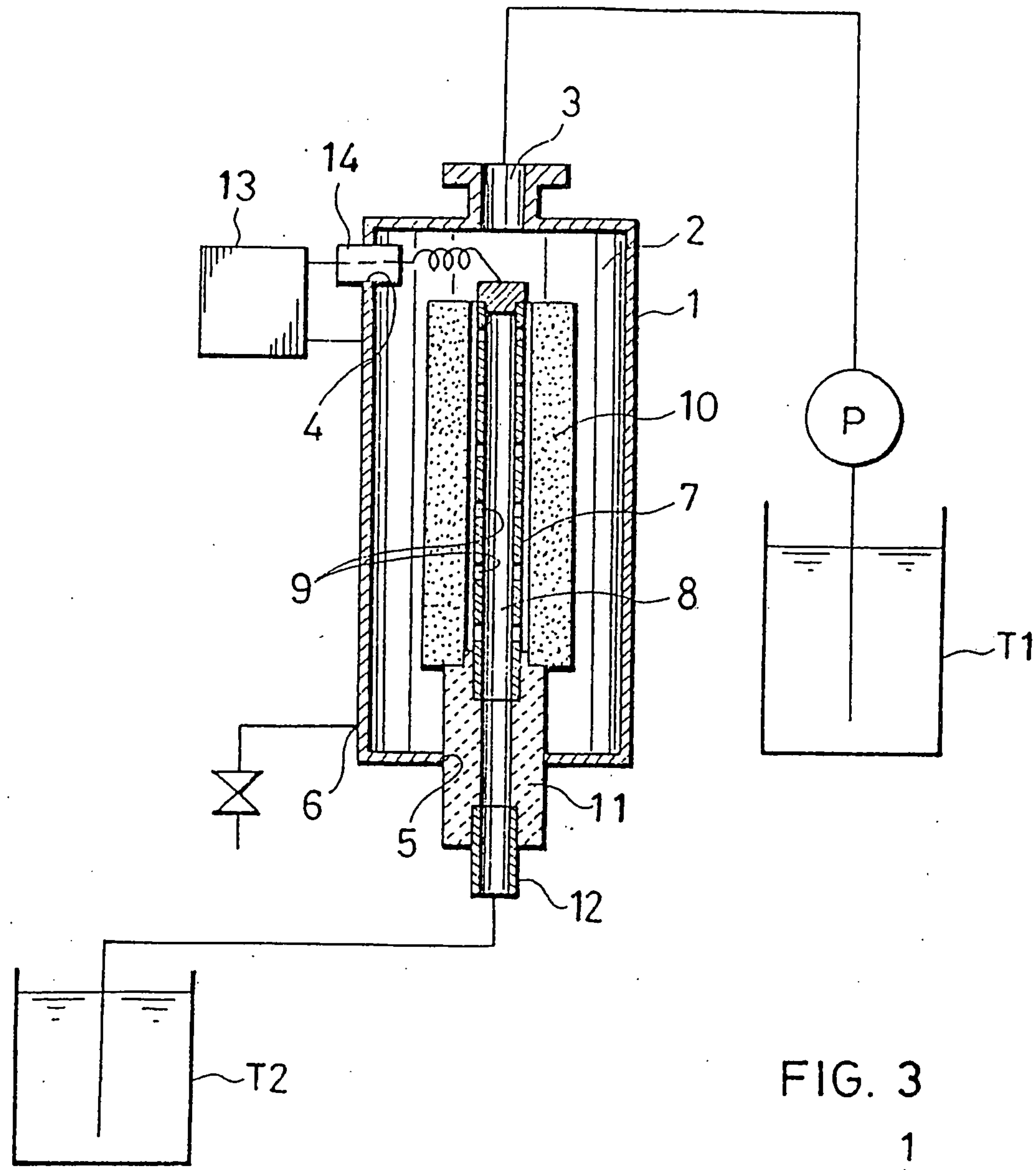


FIG. 3

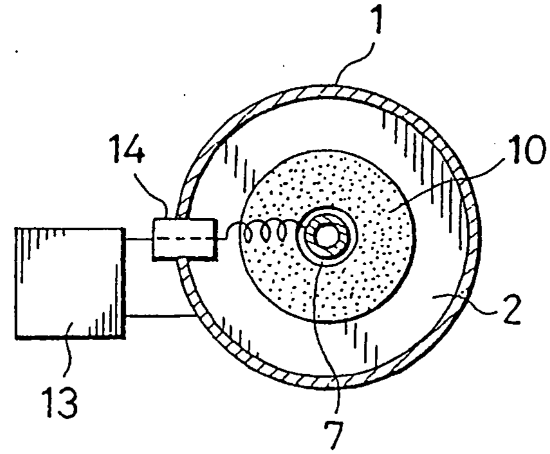


FIG. 4

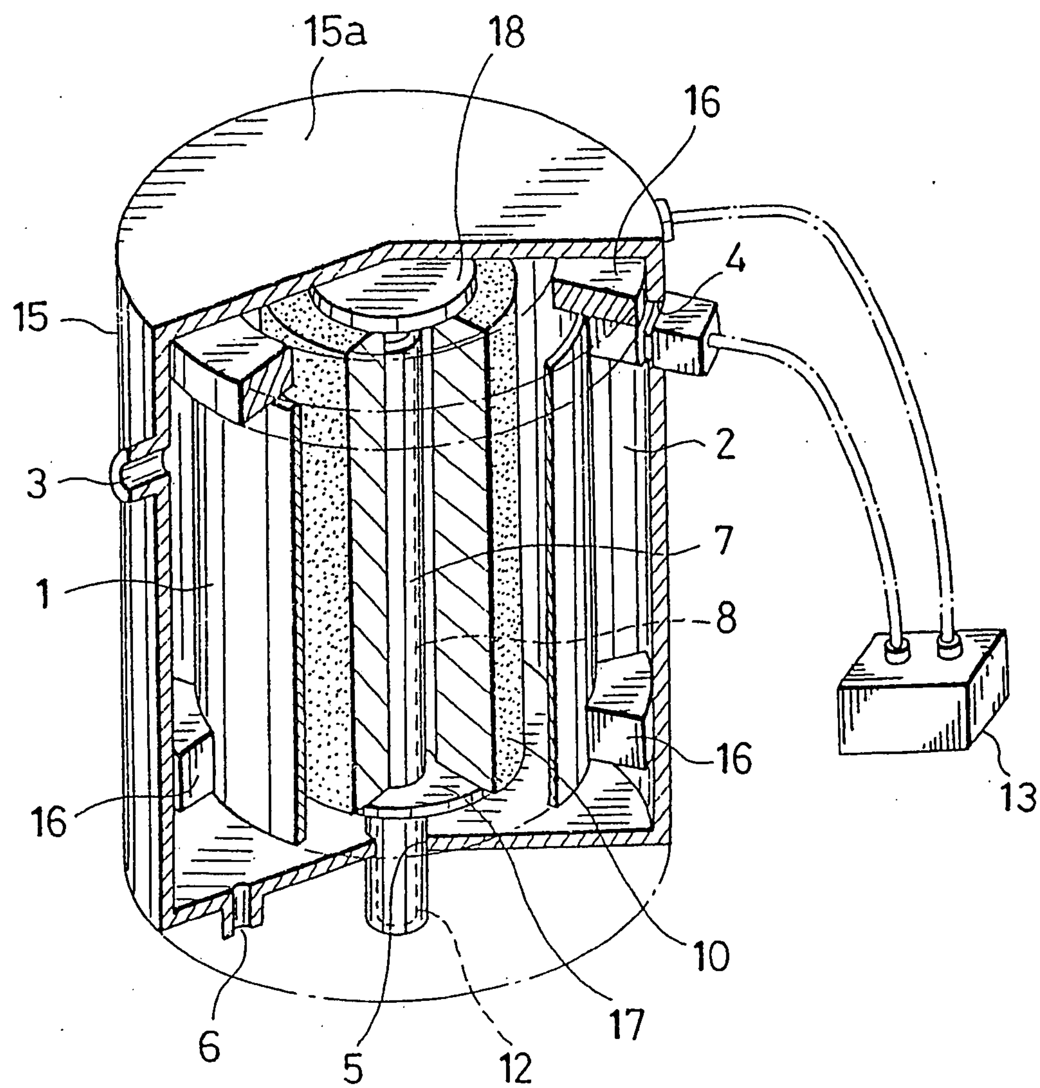


FIG. 5

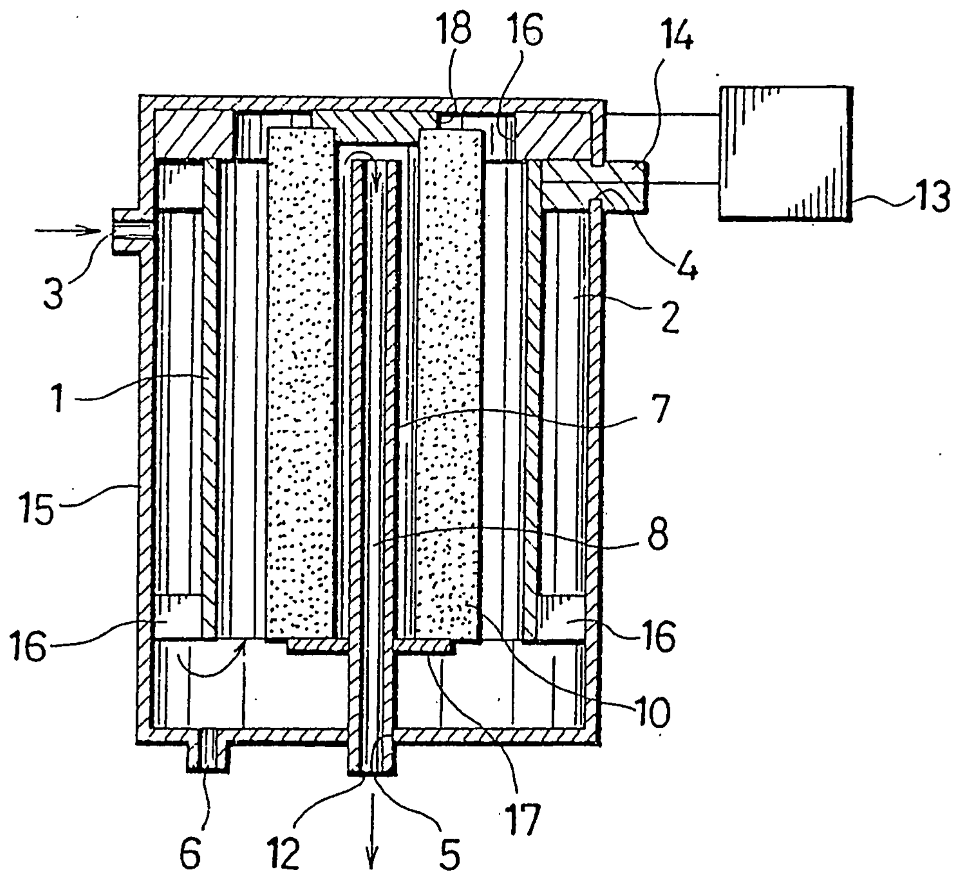


FIG. 6

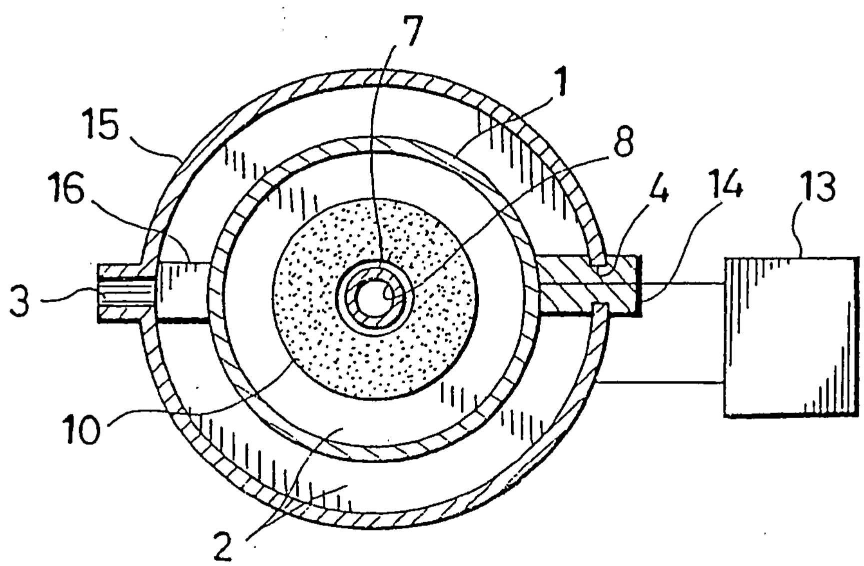


FIG. 7

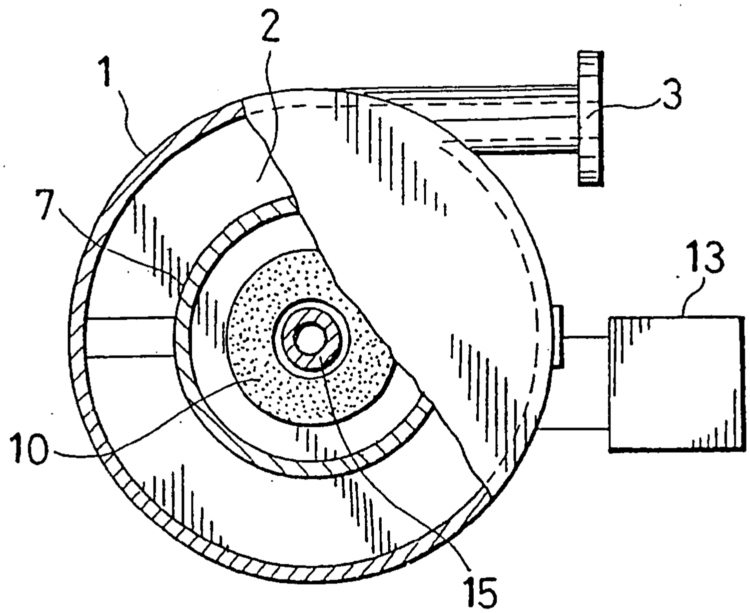


FIG. 8

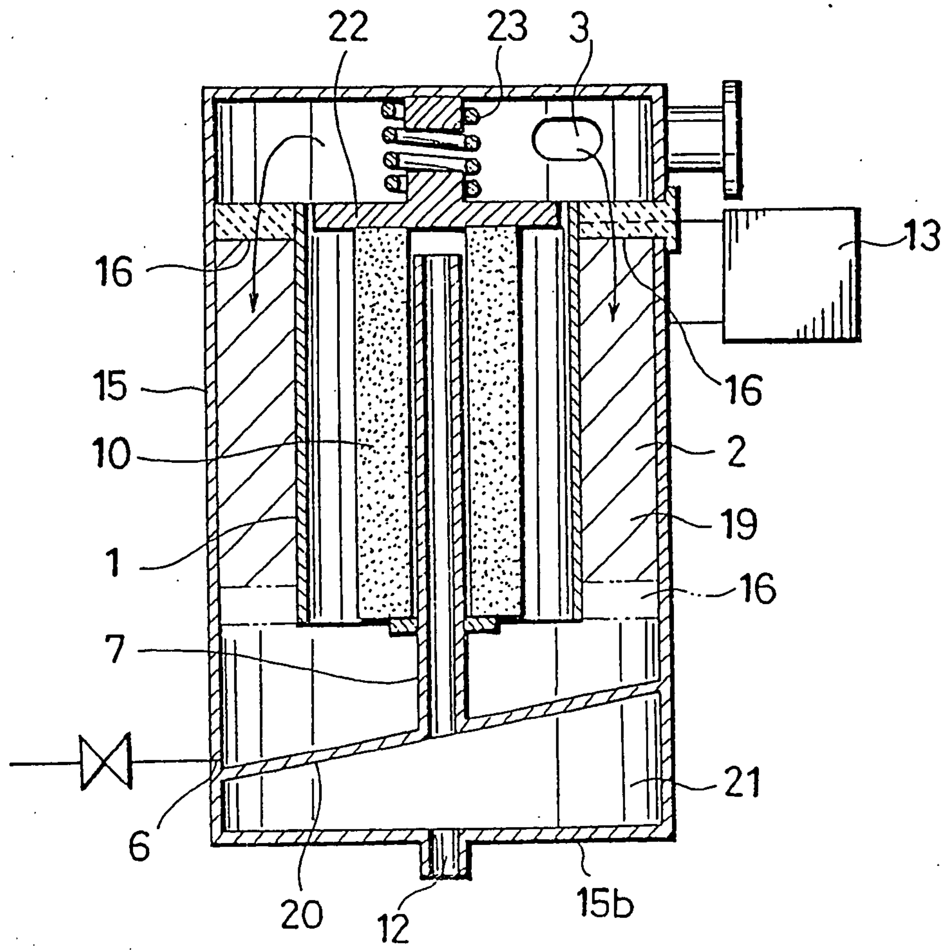


FIG. 9

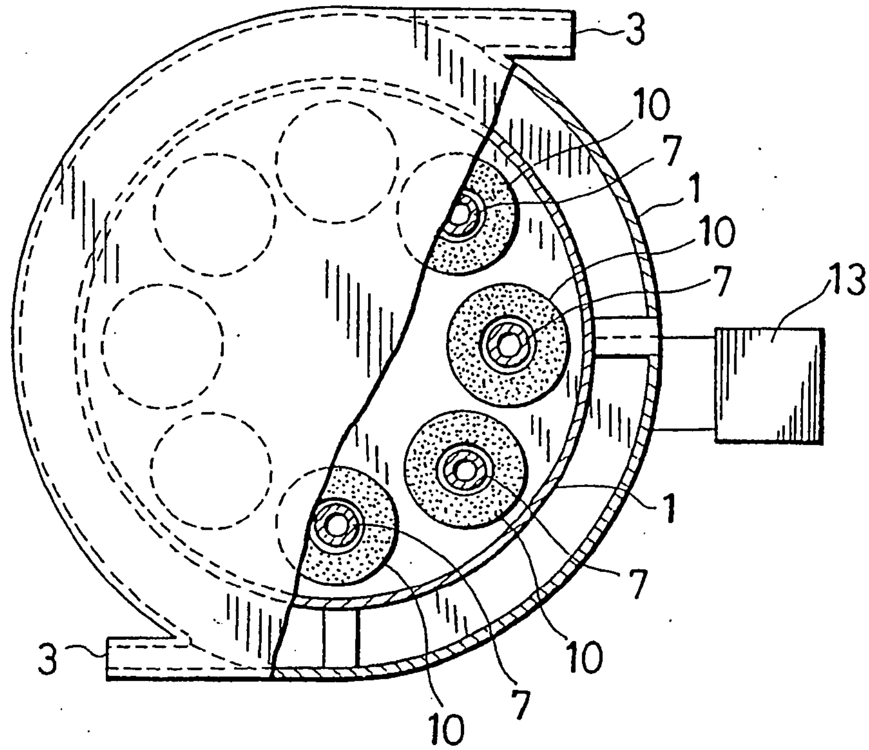
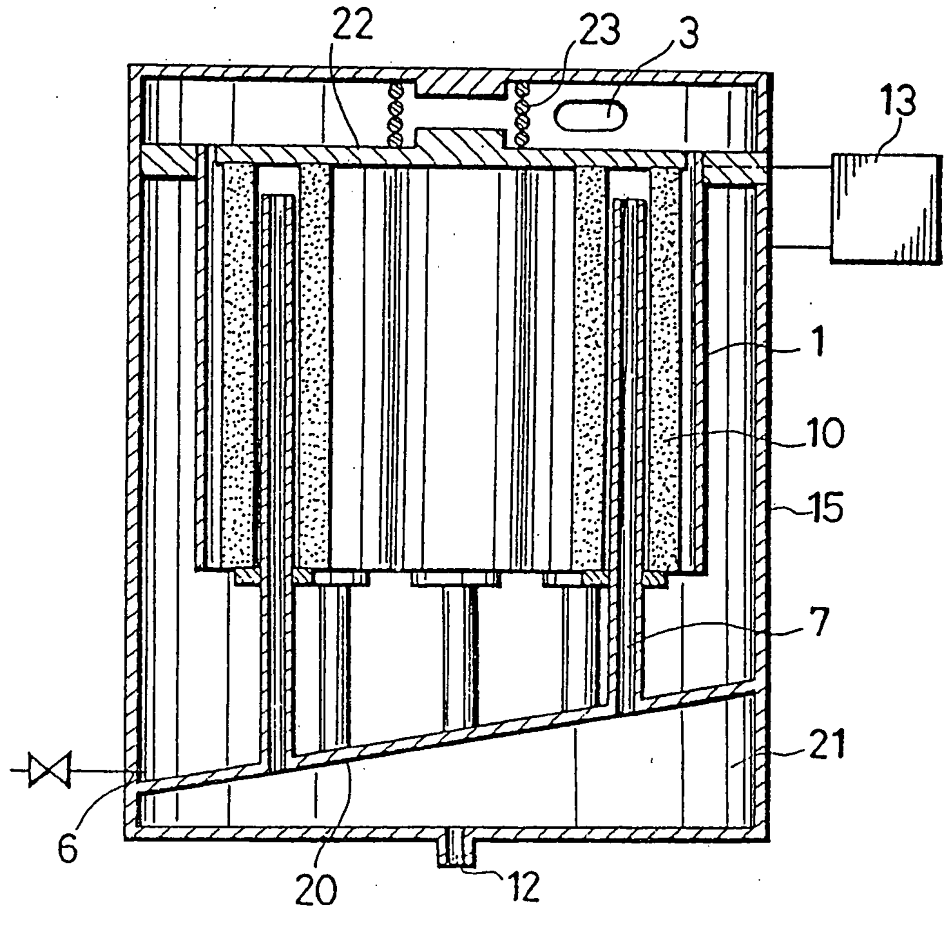


FIG. 10



SPECIFICATION

Fluid filtering apparatus

The present invention relates to a fluid filtering apparatus.

Removal of impurities contained in fluid has conventionally been carried out by use of a filtering method in which the fluid is pumped through a filter so as to remove entrained impurities, or a centrifugal settling method in which the impurities are caused to impinge against the cylindrical wall for subsequent settlement. As a solution for removal of dust from gases, it has already been proposed to impress a DC voltage in order of tens of thousand V across a pair of opposing electrodes to produce an electric discharge so that impurities in the gas passing between these electrodes are caught by the dust-collecting electrode according to so-called electric dust collecting method.

However, with such conventional apparatuses for removal of impurities according both to the filtering method and the centrifugal settling method as have been mentioned above, it is technically difficult to perform a so-called high precision filtration, for example, removal of colloidal particles and, even if any solution is found, such solution probably could not be put into practice because of unreasonable cost. A filtration precision which has recently been imposed is extremely severe, e.g., less than 1 for dust, less than 50 ppm for moisture in oil or less than 15 ppm for oil content in waste water. This requirement can not be met by either of said filtering method and centrifugal settling method. The apparatus utilizing the electric dust collecting method is certainly the apparatus of high performance which can remove particles as small as less than 1 , this apparatus must inevitably be large-sized, relatively costly and can not be used for aqueous fluid, since the use of a high voltage source requires various complicated meansures for electric insulation and safeguards against explosion. Nevertheless, there has been a strong demand for said high precision filtration as the amount of surfactant used has increased.

The filtration of colloidal matters requires the extremely high precision as set forth above, but it is hardly achieved merely by physical methods such as the filtering method and the centrifugal settling method as have previously been described. To solve this problem, the inventor proposes here a novel apparatus adapted to achieve a desired high precision filtration of fluid by eliminating a zeta potential or by controlling generation thereof, based on the realization that when the colloidal molecules or particles are charged due to induced electricity, ion adsorption or other causes, an electric double layer generates the zeta potential on the interface of said molecules or particles and the fluid, said zeta potential producing a Coulom's force among said molecules or particles, whereby said molecules or particles repel one another under effect of the Coulomb's force and are maintained suspended in the fluid and thus not readily settle down.

According to the present invention, there is provided a fluid filtering apparatus comprising a pair of opposing electrodes, a filter layer covering a surface of one of said electrodes, a voltage source for impressing a voltage across said electrodes, and a flow path adapted to guide a stream of fluid to be treated into a region between said electrodes so as to pass through said filter layer to the exterior of the apparatus.

It is believed possible by means of the present invention to provide a novel fluid filtering apparatus whereby a high precision filtration is achieved and a useful life of the filter is extended by preventing the filter pores from being clogged with impurities. Furthermore, the inventive apparatus can be used selectively for aqueous or non-aqueous liquid or gas. The apparatus can be also realized at a reasonable cost.

The invention will be described by way of example with reference to the accompanying drawings, wherein:-

Figure 1 is a partially broken perspective view showing a first embodiment of the apparatus according to the present invention;

Figure 2 is a vertical section of the apparatus shown by Figure 1 together with a diagram illustrating a pipe line associated with the apparatus;

Figure 3 is a radial cross-section corresponding to Figure 1;

Figure 4 is a partially broken perspective view showing a second embodiment of the apparatus according to the present invention;

Figure 5 is a vertical section corresponding to Figure 4;

Figure 6 is a radial cross-section corresponding to Figure 4;

Figure 7 is a partially broken plan view showing a third embodiment of the apparatus according to the present invention;

Figure 8 is a vertical section corresponding to Figure 7;

Figure 9 is a partially broken plan view showing a fourth embodiment of the apparatus according to the present invention; and

Figure 10 is a vertical section corresponding to Figure 9.

Referring to Figures 1 through 3 showing a first embodiment, reference numeral 1 designates a charging electrode in the form of a cylinder having opposite ends closed. This charging electrode 1 is provided at its upper part with an inlet 3 communicating with a treatment chamber 2 and a cable guide port 4 and at its bottom with an electrode bearing opening 5 and a drain hole 6. Reference numeral 7 designates a tubular inner electrode centrally located within the charging electrode 1. The inner electrode 7 includes a

flow path 8 axially extending therethrough and a peripheral wall which is, in turn, provided with a plurality of through-holes 9. This inner electrode 7 is covered with a filter layer 10 made of dielectric substance and the inner electrode 7 is connected at one end to an outlet 12 with interposition of an insulator 11. Reference numeral 13 designates an electric source means.

These components are assembled together by inserting the inner electrode 7 into the treatment chamber 2 through the electrode bearing opening 5 with a portion of the inner electrode being surrounded by the insulator 11 fixedly supported by said electrode bearing opening 5 so that the outlet 12 may project from the charging electrode 1. One terminal of the electric source means 13 is connected to the charging electrode 1 and the other terminal is connected by a cable extending through a lead-in insulator 14 supported by the cable guide port 4 to the inner electrode 7.

In this apparatus, as seen from Figure 2, a reservoir T_1 for liquid to be treated is in communication via a pump P with the inlet 3 and the outlet 12 is in communication with a reservoir T_2 for treated liquid.

Now a process of filtration with the apparatus shown by Figures 1 through 3 will be described.

When a voltage supplied from the electric source means 10 is impressed across the charging electrode 1 and the inner electrode 7 to place the filter 10 in an electric field, the filter 10 made of dielectric substance is polarized and an intensive zeta potential is developed on the surface thereof. In consequence, colloid particles contained in the fluid which is introduced under a pressure through the inlet 3 into the treatment chamber 2 are attracted by a Coulomb's force towards the surface of the filter 10 by virtue of the zeta potential and adsorbed thereonto. As a result of this adsorption, the colloid particles obtain a potential of the same level as that on the surface of the filter 10, lose the zeta potential and cohere together under an effect of van der Waal's force, forming a cake layer of the colloid particles on the surface of the filter 10. Such cohesion of the colloid particles occurs around respective meshes of the filter 10 so as to make the meshes of the filter 10 finer and finer and the cake layer thus formed on the surface of the filter 10 serves to block passage of impurities at a filtration precision substantially higher than the filtration precision inherent to the filter 10 itself. Advantageously, cohesion of the cooloid particles on the filter surface always occurs without causing the penetration of any particles as well as the clogging of pores of the filter 10, since the filter 10 is polarized.

Voltage supplied from the electric source means 13 is preferably a DC voltage of 1,000 to 3,000 V/cm for gaseous fluid, an AC voltage, a DC voltage or AC/DC superposed voltage of 10 to 200 V/cm for non-aqueous liquids, and an AC voltage or AC/DC superposed voltage of 1 to 20 V/cm for aqueous liquids. Selection of the type and the value of such voltage impressed depends upon the electrical resistance specific to the fluid to be handled and is preferably based on the experimental results. This means that both the type and the value of impressed voltage are not necessarily limited to those as have been set forth above. However, it should be noted that AC or AC/DC superposed voltage is preferred for aqueous fluid in view of a fact that the use of a DC voltage would cause electrolytic corrosion of the electrodes or electrolytic generation of hydrogen and oxygen.

With an AC voltage impressed, it appears that an intense agitation of the fluid occurs cyclically so that the zeta potential is eliminated or reduced by such agitation thereby causing the colloid particles to cohere together. Additionally, it appears also that a charging effect of a DC component produced by a polar effect of AC voltage contributes to said cohesion. Probably, said cohesion is caused by a synergistic effect of said agitation and said charging.

The flow velocity of fluid is determined based on the viscosity of this fluid.

Figures 4 through 6 show a second embodiment of the present invention in which an outer cylindrical electrode 15 is provided around the charging electrode 1.

Reference numeral 1 designates the charging electrode in the form of a cylinder having opposite ends opened. Reference numeral 7 designates a tubular inner electrode centrally located within the charging electrode 1, through which a flow path 8 axially extends. Reference numeral 15 designates the above-mentioned outer cylindrical electrode accommodating said charging electrode 1 and inner electrode 7 and defining therein a treatment chamber 2. This outer cylindrical electrode 15 having its opposite ends closed concentrically supports said charging electrode 7 with interposition of a protective insulator 16. The outer cylindrical electrode 15 is laterally provided at an upper portion with an inlet 3 communicating with the treatment chamber 2 and a cable guide port 4. The outer cylindrical electrode 15 is further provided at its bottom with an electrode bearing opening 5 and a drain hole 6. Said inner electrode 7 projects outwardly from said electrode bearing opening 5 and this projecting portion defines at its tip an outlet 12. The outer cylindrical electrode 15 is in contact with the inner electrode 7 at said electrode bearing opening 5 so that these outer cylindrical electrode 15 and inner electrode 7 are always at the same potential. That portion of the inner electrode 7 opposing the charging electrode 1 is covered with the filter layer 10 made of dielectric substance which is supported at one end by a supporting flange 17 formed around the inner electrode 7 and held by a top wall 15a of the outer cylindrical electrode 15 with interposition of an insulator 18 spaced from the upper end of the inner electrode 7. Reference numeral 13 designates an electric source means.

In this embodiment constructed as has been described above, the fluid introduced under a pressure through the inlet 3 flows downwards between the outer cylindrical electrode 15 and the charging electrode 1, then through the filter layer 10 into the flow path 8 extending through the inner electrode 7 from the upper end thereof and finally discharged through the outlet 12.

Now the manner in which [illegible] apparatus operates will be considered. Wi[illegible]is embodiment of the inventive apparatus, the fluid introduced under a pressure through the inlet 3 first passes through the electric field generated between the outer cylindrical electrode 15 and the charging electrode 1. As a result, colloid particles carrying zeta potential thereon are collected under the effect of a Coulomb's force onto the surface of the charging electrode 1, which eliminates their zeta potential. After the zeta potential has been eliminated, there remains only the van der Waal's force acting among individual colloid particles, and the particles then cohere together under the effect of such intermolecular attraction into coarse particles. The colloid particles thus cohering together into coarse particles are caused to settle down for separation as these coarse particles each have a specific gravity higher than that of the fluid itself. Examples of these particles which can br settled include particles in gases, moisture or other particles in oil or SS content in water. The colloid particles thus cohering together in to aggregates are floatably separated as these coarse particles each have a specific gravity lower than that of the fluid itself, as the oily content in water. When the fluid is aqueous, metallic ions produced by electrolysis of water due to the impressed voltage function to eliminate the zeta potential carried by the colloid particles, causing these cooloid particles to cohere together or causing active metallic hydraoxides to envelope colloid particles and co-flocculate therewith, providing a synergistic effect.

The remaining colloid particles which do not cohere together and settle doen are now collected on the filter 10 as they flow along the flow path. A zeta potential is produced on the surface of the filter 10 due to the electric field developed by the voltage impressed across the charging electrode 1 and the inner electrode 7 and, in consequence, said colloid particles form a cake layer on the surface of the filter 10 just as in the first embodiment.

As will be obvious from the aforegoing description, the apparatus according to this embodiment is so constructed as to eliminate the zeta potential carried by colloid particles in the region between the outer cylindrical electrode 15 and the charging electrode 1 prior to the fluid passing through the filter 10 placed under the influence of the electric field, causing the cooloid particles to cohere together and thereby to settle or to float. Thus, the impurities of relatively large particle-sizes can be removed before passage through the filter 10 and the latter has its load reduced and its useful life extended. Furthermore, it is also possible to achieve a high filtration precision after a few cycles of filtration.

Concerning the type as well as the value of voltage impressed across the charging electrode 1 and the inner electrode 7 or the outer cylindrical electrode 15 and other factors such as the velocity of fluid, selection may be done as in said first embodiment.

Figures 7 and 8 show a third embodiment of the present invention so constructed that the inlet 3 is arranged above the treating chamber 2 so as to introduce the fluid tangentially with respect to the inner periphery of the outer cylindrical electrode 15 and that a dielectric 19 made of glass wool or the like is interposed between the outer cylindrical electrode 15 and the charging electrode 1. Basically, this third embodiment is identical to said second embodiment and comprises the charging electrode 1 in the form of a cylinder, the inner electrode 7 centrally located within said charging electrode 1. The outer cylindrical electrode 15 is at the same potential as the inner electrode 7 and adapted to accommodate therein said charging electrode 1 and said inner electrode 7. The inner electrode 7 is covered with the filter 10 made of dielectric substance. As has already been mentioned, the apparatus according to this embodiment has the inlet 3 arranged above the treatment chamber 2 so as to introduce the fluid tangentially with respect to the inner periphery of the outer cylindrical electrode 15. Accordingly, the fluid is uniformly introduced into the region between the outer cylindrical electrode 15 and the charging electrode 1, then into the treatment chamber 2 as said fluid spirally rotates. This enables the surface of the charging electrode 1 to be effectively used during attraction of the colloid particles under the effect of a Coulomb's force thereonto.

Another feature of this embodiment is that the dielectric 19 such as glass wool is advantageously interposed between the outer cylindrical electrode 15 and the charging electrode 1 in that said dielectric 19 is polarized upon impression of a voltage across said outer cylindrical electrode 15 and the charging electrode 1 with the net effect that a plurality of electrodes are interposed between said outer cylindrical electrode 15 and said charging electrode 1. Thus, cohesion of the colloid particles occurring between the outer cylindrical electrode 15 and the charging electrode 1 is further promoted and, as a result, the filtration precision as well as the useful life of the filter 10 can be improved.

In this embodiment, the outer cylindrical electrode 15 is connected with the inner electrode 7 by a sloped wall 20 which defines a filtrate collecting chamber 21 isolated from the treatment chamber 2, between said sloped wall 20 and the bottom 15b of the outer cylindrical electrode 15. The drain hole 6 is provided at the lowest level of the treatment chamber 2, i.e., in the side wall of the outer cylindrical electrode 15 adjacent the lowest end of said sloped wall 20 while the outlet 12 is arranged in the bottom of the outer cylindrical electrode 15. As a consequence, the impurities having settled within the treatment chamber 2 are effectively discharged through the drain hole 6.

Reference numeral 22 designates an insulating plate which serves to prevent the filter 10 from being lifted by a stream of fluid flowing upwards and which is held by a spring 23 extending between the top of the chamber 2 and the inner surface of the top of the outer cylindrical electrode 15.

Figures 9 and 10 show a fourth embodiment of the present invention in which there are provided a plurality of inner electrodes 7 within the cylindrical charging electrode 1. This embodiment is suitable for

large-scale filteration and is constructed that a pair of inlets 3 are tangentially arranged and a plurality of (eight in Figure 9) inner electrodes 7 each covered with the filter 10 are vertically supported along the inner peripheral surface of the charging electrode 1. The rest of the construction is same as in the precedent embodiments. Provision of many inner electrodes 15 each covered with the filter 10 advantageously contributes to improvement of the treating capacity.

The fluid filtering apparatus of the present invention as has described hereinabove may be effectively used for removal of fine particles from gases such as air, for dehydration and fine particle removal of non-aqueous lubricating oil, machining oil, cleaning oil or the like, and for removal of oily content or fine particles from aqueous pure water, waste water, potable water, lubricating liquid, working liquid, flushing liquid or like.

Here will be set forth experimental data which were obtained by operating a trial apparatus of the present invention particularly corresponding to the second embodiment thereof.

a. Removal of fine particles from nitrogen gas:
gas flow rate: 0.5 m^3/Hr, charging voltage: 5000 VDC/3cm,
sample particles: dust of 0.1 to 1 μ, filter: 1 μ nominal,
pass: 1

	Before treated	*After treated*
Voltage impressed	112 mg	0.2 mg
No voltage impressed	118 mg	45.2 mg

It is obvious that the treating capacity is improved by voltage impression.

b. Comparative filtering test for lubricating oil utilizing DC and AC charging:
gas flow rate: 1 ℓ/min, charging voltage: AC and DC 0 to
1000 V/3cm, filter: 1 μ nominal, viscosity: 56 Cst,
temperature: 25°C.

Charging voltage	*Moisture ppm*	*Impurities mg/100cc*
Before treated	3,237	114.4
No voltage impressed	1,850	21.8
25VAC	980	10.2
25VDC	958	9.2
100VAC	560	7.0
100VDC	545	6.9
250VAC	524	6.8
250VDC	514	6.8
500VAC	483	6.8
500VDC	339	5.6
1,000VAC	1,000	10.8
1,000VDC	990	10.0
3,000VAC	980	12.3
3,000VDC	910	11.9
5,000VAC	905	13.9
5,000VDC	847	13.4
10,000VAC	850	17.1
10,000VDC	840	16.6

The data set forth in the above table indicate that both AC and DC may be utilized without any significant difference in effect but the DC charging provides an effect slightly better than AC charging. It appears that DC 500 V is optimal for generation and elimination of zeta potential. It will be also obvious from these data that, with the fluid filtering apparatus of the present invention, the treating capacity is lowered as the voltage to be impressed exceeds a level of 500 V both in the cases of AC and DC. This suggests that the removal of impurities is effected on the basis of a principle substantially different from the principle of the electric precipitation as has commonly been employed.

c. Removal of metallic salts from aqueous glycol solution:
flow rate: 1ℓ/min, charging voltage: AC 25V/3cm,
filter: 1 μ nominal, Viscosity: 46 Cst,
temperature: 25°C, total amount: 20ℓ.

Passes / *Items*	*0*	*1*	*2*	*3*	*4*
No voltage impressed, contamination degree mg/100 cc	13.5	10.8	8.6	6.9	5.5
Voltage impressed, contamination degree mg/100 cc	13.5	4.5	1.2	0.4	0.2

These data were obtained utilizing AC 25V/3cm as the impressed voltage to inhibit a possible electrolytic corrosion and indicate that the filtering capacity can be significantly improved also by use of AC voltages.

d. Treatment of oil-containing waste water:
flow rate: 1ℓ L/min, filter: 1 μ nomila.
(Glass wool was interposed between the outer cylindrical electrode and the charging electrode, provided that 12VDC/12VAC superposed voltage was impressed.)

	AC 25V/3cm, 10 passes		*12VDC/12VAC superposed/3cm, 5 passes*	
treated	*Before treated*	*After treated*	*Before treated*	*After*
Oily cont. mg/	8,250	78	8,250	63
SS cont. mg/	856	45	856	40.5
BOD cont. mg/	188	18.2	158	15.3
COD cont. mg/	136	48.6	136	36.2

Impression of AC/DC superposed voltage with interposition of glass wool between the outer cylindrical electrode and the charging electrode resulted in a better filtering effect with a fewer passes than the case in which only AC voltage was impressed.

It will be apparent from these data that the fluid filtering apparatus constructed in accordance with the present invention can achieve the filtering effect of extremely high precision no matter whether the fluid to be treated is gas, non-aqueous liquid or aqueous liquid.

The present invention is not limited to the embodiments as have been described hereinabove, so long as one of the opposing electrodes is covered with a filter made of dielectric substance, a voltage is impressed across said opposing electrodes in order to polarize the filter placed in the electric field and the fluid is introduced under a pressure into the region between said electrodes before passage through the filter.

CLAIMS

1. Fluid filtering apparatus comprising a pair of opposing electrodes, a filter made of dielectric substance covering a surface of one of these electrode, a voltage source for impression of a voltage across said electrodes, and a flow path guiding the fluid introduced under a pressure into the region between said electrodes to flow through the filter and then to be discharged into the exterior.

2. Fluid filtering apparatus according to Claim 1, wherein said opposing electrodes comprise a cylindrical charging electrode and a tubular inner electrode located within said charging electrode and wherein the surface of said inner electrode is covered with the filter so that the fluid having passed through the filter is discharged from one end of said inner electrode.

3. Fluid filtering apparatus according to Claim 2, wherein there is provided an outer cylindrical electrode accommodating therein said charging electrode and said inner electrode, said outer cylindrical electrode being insulated from the charging electrode and being at a same potential as said inner electrode, so that the fluid introduced under a pressure into the region between the outer electrode and the charging electrode further flows into the region between the charging electrode and the inner electrode.

4. Fluid filtering apparatus according to Claim 3, wherein above the opposing portions of the charging electrode and the inner electrode within the outer cylindrical electrode, there is provided an inlet adapted to introduce the fluid under a pressure tangentially with respect to the inner periphery of the outer cylindrical electrode.

5. Fluid filtering apparatus as claimed in any one of Claims 2 to 4, wherein there are provided within the charging electrode a plurality of inner electrodes each covered with the filter.

6. Fluid filtering apparatus as claimed in any one of Claims 2 to 6 wherein there are provided through-holes in the peripheral wall of the inner electrode.

7. Apparatus as claimed in Claim 1 and substantially as herein described with reference to and as illustrated in the accompanying drawings.

8. Each and every novel embodiment herein set forth taken either separately or in combination.

Printed for Her Majesty's Stationery Office by Croydon Printing Company (UK) Ltd, 12/86, D8817356.
Published by The Patent Office, 25 Southampton Buildings, London WC2A 1AY, from which copies may be obtained.